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AvantGuard: An Instrument to Explore
Issues of Autonomy

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May 2005

Final Report for May 2004 to February 2005

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Human Effectiveness Directorate
Warfighter Interface Division
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FOR THE COMMANDER

//Signed//

MARIS M. VIKMANIS
Chief, Warfighter Interface Division
Air Force Research Laboratory

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14. ABSTRACT

AvantGuard is an instrument with which researchers can study the interplay of human direction and autonomous behavior in conducting a simulated mission where a human supervises multiple autonomous Unmanned Air Vehicles (UAV). AvantGuard is a computer game in which UAVs are used to protect a convoy moving through unsecured urban terrain under conditions of asymmetric conflict. Adversaries hide among the residents and prepare an ambush. The operator directs small UAVs and studies the resulting sensor stream to find the ambush before the convoy arrives in the trap. Autonomy is decomposed into four cognitive phases: look, see, decide, act. Each is matched to an exemplary task: sensor location, image analysis, threat assessment, and convoy rerouting. Each of these is independently assigned a Level of autonomy, or an adaptive strategy. Using sophisticated game techniques, a high-performance UAV simulation game prototype was developed, as well as the design for the experimenter interface.

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AvantGuard: An instrument to explore issues of autonomy.

Dov Jacobson, GamesThatWork
Final Report to:
Gloria Calhoun, AFRL/HE; Mark Draper AFRL/HE

ABSTRACT

AvantGuard[1] studies the interplay of human direction and autonomous behavior in conducting a simulated mission.

It is a computer game in which Unmanned Air Vehicles (UAVs) are used to protect a convoy moving through unsecured urban terrain under conditions of asymmetric conflict. Adversaries hide among the residents and prepare an ambush. The operator directs small UAVs and studies the resulting sensor stream to find the ambush before the convoy arrives in the trap.

AvantGuard serves those who seek to improve the effectiveness of the UAV mission. It is an instrument with which researchers can measure performance as they develop new systems.

It is particularly designed to study the interplay of human supervisor and autonomous UAVs. Its cognitive challenges are organized into distinct tasks. For each task, the autonomy level of the UAV is set independently. Calibrated to independent standards, results can be compared to one another and to the findings of other researchers.

By addressing real-world problems, such as battlefield constraints on bandwidth and the limits of machine vision, AvantGuard presents a credible approach to mission simulation, training and eventual execution. By employing sophisticated game techniques, AvantGuard advances an innovative design. By considering the post-combat role of the military, it prepares an instrument to advance the goals of peace as well as those of war.

1

OVERVIEW

1 The Goals of the Project

The principle goal of this project is to maximize the effectiveness of those airmen who direct groups of unmanned air vehicles. Effectiveness is increased when the human attention is cleared of concerns that can be delegated profitably to machines and is provided with awareness of situation and consequence which is clear, deep and easily navigable.

This project exists to help Air Force scientists discover the principles by which autonomous entities can assume certain responsibilities without compromising human intent and by which they can focus human attention without distorting the sensed world.

There are two minor goals to which this project also commits. These goals can be achieved without detracting from the primary goal. Rather, simultaneous pursuit of all three goals seems likely to enhance the likelihood of success for each of them.

The secondary goal is to explore tactics for a particular application of UAVs. AvantGuard studies an urban asymmetric confrontation. It proposes a particular arrangement of sensor-bearing UAVs, highly interactive control system, convoy routing protocols and a trained airman. Autonomy is distributed complexly throughout this system. By envisioning and testing this system, the developers examine a new approach to a serious wartime problem.

When this problem is extrapolated forward into a post-combat environment, it is seen that the challenges of peace can exceed those of war. Existing concepts must deepen and all the intelligences must become more subtle. The ambition of this project does not extend to solving these challenges – only to elucidate them.

The third stated goal of AvantGuard is to demonstrate the effectiveness of a user interface whose roots lie in videogame development – rather than Human Factors engineering. This DNA will be obvious in the visuals it presents, in the controls it affords and in the comfort it assumes that the human has with artificial entities who display independent behavior.

1.1 Scope

Ambitious goals can inspire fine achievement. But, ill-managed, they court failure. Stepwise approach to meeting these goals is essential to project stability and success. The most simple breakdown is the one enforced by Air Force funding policies: a Phase I dedicated to proof of concept and a Phase II which results in a functional prototype.

1.1.1 Phase I

Phase I aims to communicate the experimental concept. Vigorous software development effort renders the proposed user experience in a tangible and visible form. This example supports an experimental plan to address rigorously the issues of autonomy.

1.1.2 Phase II

The experimental plan has been formalized as a Phase II proposal. That plan details the structure of the completed AvantGuard software and the scientific inquiry for which it is designed.

1.1.3 Documentation

Both the existing software achievements and the final product blueprint are summarized in this report. Interested readers are referred to the Final Summary Video[2] for a focused view of the proposed user experience.

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[2] Available for download at http://GamesThatWork.com

2 Human and Artificial Intelligence

AvantGuard isolates a problem and presents a treatment which employs both autonomous UAVs and human judgment. It is a meaningful mission – low, slow reconnaissance in an urban environment, protecting a moving convoy.

Resources are limited: UAV locations, sensor bandwidth, and time remaining before convoy arrival. But the most critical resource is the single human intelligence. No machine vision can distinguish threats in this complex environment, where a shovel might be more ominous than a grenade launcher. This project aims to focus human intelligence on critical judgments by assigning other decisions to autonomous entities.

3 Issues of Autonomy

The immediate aim of this project is a functional and flexible testbed to address the principles of autonomy design at the Air Force Research Laboratory, Human Effectiveness Directorate (AFRL/HE). The testbed must deliver valid scientific results that are reproducible both in that lab and elsewhere.

3.1 Autonomy has value

3.1.1 Reducing warfighters' exposure to danger.

No-one doubts the courage of American pilots. But there are many missions in which their commitment would be squandered. Some tasks present tedium beyond human tolerance. Some have very high risk but offer only modest rewards. Some flights can have no return. UAV technology enables these previously impossible missions.

3.1.2 Enabling innovation.

Without the burden of supporting a crew, the UAV escapes many design constraints. It needs no cockpit. It can exceed human-tolerable G forces. Or it can be six inches long. UAV technology enables these previously impossible designs.

3.1.3 Eliminating costs.

Safety, comfort and life support systems can be stripped from the design. Weight is reduced, maintenance is easier.

3.1.4 Decreasing operational manpower requirements.

Unlike manned craft, the crew of a UAV can be less than one. However this is not true of all UAVs. Although remotely-piloted UAVs reduce danger and eliminate costs, in operation they require no less attention than manned craft. The Predator has a (remote) crew of 2. To realize a manpower savings, engineers must introduce autonomy into UAVs.

3.2 But autonomy brings problems.

3.2.1 Judgment vs. Heuristics

Important decisions often require high-level pattern recognition or sophisticated inference. Frequently they require creative thought. They may demand a complex synthesis of disparate factors. Humans perform such reasoning better than computers. When such decisions are consequential, designers will temper UAV autonomy with human supervision.

3.2.2 Automation compromises performance

Researchers in this field have named many of the vulnerable points where automation corrupts competent operators:

- **Automation bias**   [Skitka 2000]
  Operator reasoning is impaired by excess credence given to the machine's suggestions.
- **Complacency**   [Knapp 1991]
  Operator unconsciously neglects attention to work shared with automation.
- **Workload Imbalance**   [Yeh 2001]
  Automation distorts the job, forcing greater attention to lesser tasks.
- **Skill Degradation**   [Parasuraman 2000]
  Human skills which are performed by automation fall out of practice.

- **Over-reliance**   [Wickens 1999]
  Operator consciously denies responsibility for automated tasks.
- **Attention Narrowing**   [Mosier 1998]
  Decision-making is impaired by misdirected attention or by filtered sensor data.
- **Mistrust**
  Unwarranted bias to discount machine decisions, often based on an atypical experience.
- **Impaired vigilance**   [Molloy 1996]
  A species of reliance exacerbated by boredom, that increases over time.

3.3 Autonomy design has many dimensions

3.3.1 Autonomy has many levels.

UAV autonomy demands interplay between man and machine. It is this interplay - not AI algorithms – that lies at the heart of Level of Autonomy design. The levels are marked by differences in notification, consent, and exception, and commonly parsed into linear scales of automation, such as the ten-level scales proposed by Sheridan [1983], [2000].

3.3.2 Autonomy has many domains.

Each decision has several cognitive steps. These have clear dependencies, but they do not necessarily occur in order. By breaking behavior into these domains of cognition, autonomy design for each domain can be considered individually.

3.3.3 Autonomy has many phases.

The pattern of autonomy levels is not static. It must adapt. For example: autonomous re-planning might be inappropriate during typical mission execution, but might be a necessity during an episode of catastrophic overload.

3.4 Tools for Autonomy Design

Design of a system with so many variables requires guidance. Researchers support designers by proving principles and providing guidelines. To do so, the researchers require good tools. AvantGuard is such a tool. It presents a timely and relevant task in a compelling videogame format. The difficulty of the task is open-ended: as automation (or skill development) reduces the task pressure, more work load can be readily added by the researcher.

The cognitive demands of the game divide cleanly into five distinct tasks. Each is unambiguously identified within a widely accepted system of categorization. For each, the researcher sets a Level of Autonomy (LoA). The settings refer to an array of distinct behaviors, arranged on an ordinal scale, calibrated to an independent standard.

Finally it offers the researcher several modalities for adaptive Level of Autonomy. Broad standards for Adaptive LoA (ALoA) have yet to be established. (Perhaps some will emerge from this tool.) The tool supplies certain 'natural' algorithms for Adaptive Level of Autonomy. Also it invites creativity: A Finite State Machine offers the researcher a simple and flexible approach to original ALoA strategies. A user-friendly tool allows non-programmers to compose such strategies.

4 Game Techniques

Even if game interface conventions had no inherent superiority, they would be worth adopting: Big gains in performance and in learning curve reduction are available by simply exploiting the existing highly developed skills of a gamer generation. Maintain a videogame sensibility, and tap into that training.

But Hollywood game techniques are not arbitrary. They are highly evolved designs that optimize situation awareness, reaction time and engagement. AvantGuard explores a variety of techniques familiar to gamers.

4.1 Cinematography

Attention is directed – and situation awareness is sharpened – by dramatic staging, framing and lighting.
Rich models of realistic scenes increase verisimilitude and engagement. Simplicity clarifies symbolic scenes involving cartographic, diagrammatic, abstract data representation.

4.2 Camera

Camera moves add situation awareness. They display three-dimensional relationships better than a static viewpoint can.

4.3 Challenges:

Well designed challenges sharpen attention – rather than distract.
Visible score maintains focus on goal. "Personal Best" is an eternal challenge.

4.4 Control

Complete control of point-of-view and moving through sensor stream database.
Two handed (keyboard and mouse) control, or traditional game controller: fast, accurate, known.

4.5 Customization

AvantGuard, like most complex modern computer games, facilitates customization (Game Mods) by its users.
The best of these modifications improve the fidelity of the scenarios by incorporating actual experience.

4.6 Community

Multiplayer networks allow users to share learning within the game itself, through conversation or observation.
Online exchange of Mods – posted on websites or exchanged through email allow rapid emergence of quality.

4.7 Competition

Performance is enhanced by competition for scores. Creative solutions emerge from competition for mod popularity.
Competitive antagonistic play brings out better performance on both sides, far better than artificial intelligence.

4.8 Composition

There is a potential for musical elements to convey certain elements of awareness as they do in popular games.
Music arguably reduces fatigue and boredom.

4.9 Creative Effects

Visuals effects stimulate and refresh the operator. They can emphasize elements that require special attention.
Sound effects and haptics add more dimensions of sensory involvement.
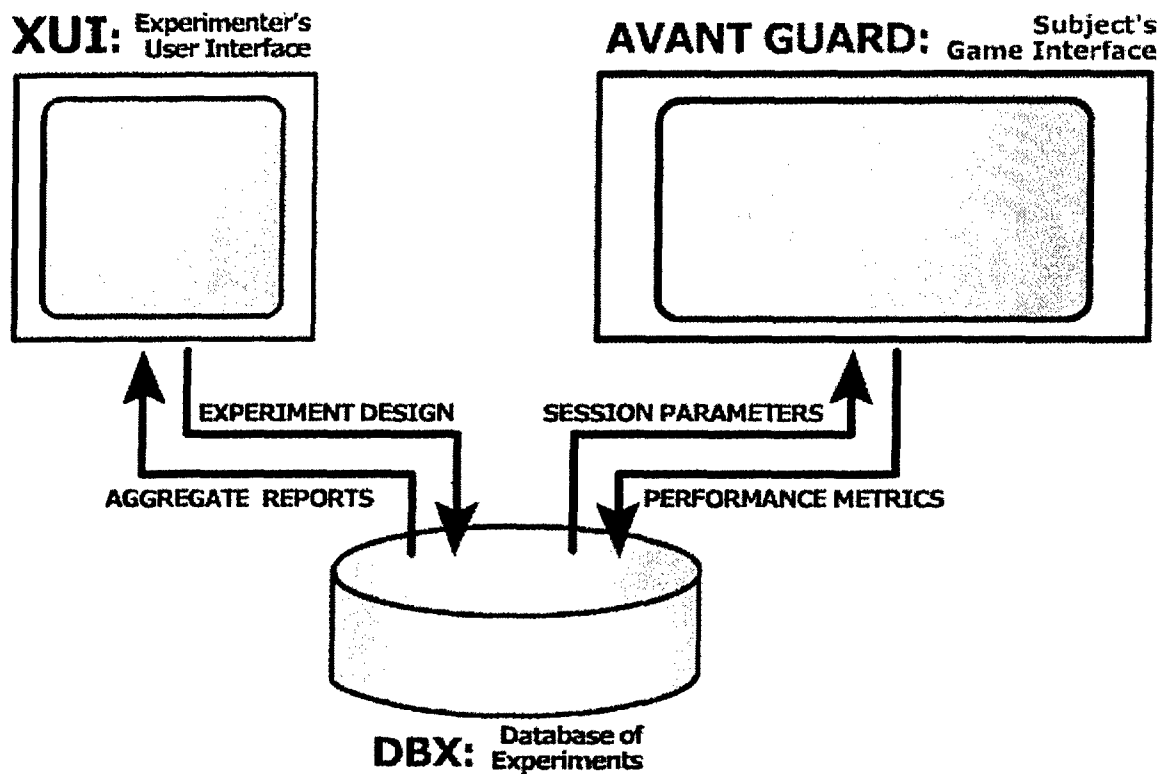
4.10 Conversation

Speech Recognition is used (starting in Phase I) to reroute the convoy.
Interactive Voice Response (Phase II) add depth to the convoy routing phase by simulating human conversation.
It has the potential to speech-enable other parts of the human-machine dialogue.

5 Three Tier Architecture

The experimental system has a straightforward architecture. Three networked processes manage different functionality. Phase I resulted in a broad functional specification of two of these processes: Database of Experiments (DBX) and Experimenter's User Interface (XUI). The third process, the AvantGuard Game Interface, has been developed in far more detail.

XUI: Experimenter's User Interface   **AVANT GUARD:** Subject's Game Interface

EXPERIMENT DESIGN   SESSION PARAMETERS

AGGREGATE REPORTS   PERFORMANCE METRICS

DBX: Database of Experiments

5.1 DBX: Database of Experiments

A network server hosts a Relational Database Management System. This holds the entire history of the experiments: each study is characterized by an Experiment Design and by the large body of results. These results can be examined in detail or in aggregate using a standard query language, SQL. AFRL researchers can easily perform statistical analyses on the simple results of the experiments. Careful database design facilitates creative data-mining. The same results can be re-explored using fresh models - and previously unanticipated correlations can be discovered.

Finally a networked server and a clearly designed SQL database offers investigators the ability to publish raw data. Peers can verify the conclusions of the authors. Fresh minds can interpret these results from a new perspective. A ready-for-public relational database management system will allow investigators to publish data easily in the widely accessible XML (Extensible Markup Language) format.

5.2 XUI: Experimenter's User Interface

The researcher will typically not work at a game machine, nor the database server, but at an ordinary office computer, possibly remotely. The Experimenter's User Interface affords the researcher the big picture – and the small details of the study. The XUI is an online interface to the database server accessible with a simple web browser. It is presented on a web client, with the application running on the server as middleware logic, interfaced locally with the SQL server.

5.2.1 XUI for the Experiment Designer

The experimental design package allows the Principal Investigator to establish the scope of a study. The sample size, controls, independent and dependent variables are identified. Experiment design methodologies such as factorial, fractional, and nested design will be supported. The product of this designer's effort is recorded in the database, not only as study parameters, but as a new relational table structure, designed to capture these specific experimental results.

5.2.2 XUI for the Research Manager

Administrative tools of the XUI are concerned with operational aspects of an experimental run. It includes the interface with which individual subjects are enrolled, debriefed and tracked. Management of the sample population is built in. For example, blind blocked randomization of subjects into control and experimental groups.

5.2.3 XUI for the Session Monitor

During actual experimental session, the XUI registers the subject and launches the appropriate session. As the session is executed, it records performance metrics of the subject.

5.2.4 XUI for the Scientist

Finally the XUI can be used to extract and present results. Simple metrics can be queried individually, or in the aggregate. Results can be displayed graphically – in a format conducive to public presentation.
The XUI offers limited statistics and graphics for quickly browsing experimental results. It will not attempt to reproduce a full statistics package. But neither does it limit inquiry. Researchers can compose any SQL expression in the interface and download the results in XML format. Unlimited statistical analysis can be performed on these data with an appropriate mathematics package.

5.3 AvantGuard: The Game Interface

The AvantGuard application runs well in standalone mode for testing and development. Before actual experimentation, it is configured by parameters (such as Level of Automation points) in the database. Detailed designs of the urban landscape and its threats are also loaded from repositories on the server. During the experimental session, data streams from this client to the server, where it is recorded – and optionally formatted for real-time display to the researcher. At the end of the session, summary tables are developed in the database.

There is another use for this high performance "game computer". Researchers will use it when developing a set of challenges for an experimental session. AvantGuard provides a complete "level editor" with which a researcher can place and program a wide variety of humans, vehicles and weapons. The resulting design is stored on the database server. During experimental design, the researcher chooses among these scenarios. The active scenario design is archived by the server and remains available even if the file is later lost or modified.

6 Autonomy Controls

6.1 Parasuraman Domains

Parasuraman's four domains of cognition form a useful tool for organizing the issues of autonomy.
Reduced to monosyllables, these are: Look, See, Choose, Act.
We have organized the cognitive tasks of AvantGuard into the four Parasuraman Domains. The tasks are actually divided into five distinct processes, with two different Domain 1 tasks, one creative and one technical. These are listed in the table below and explained in detail in the following pages.

6.2 Sheridan Levels

Each of the tasks has a strategy to implement all ten of the Sheridan [2000] levels of automation. These had to be artfully composed. All strategies fit the definitions, but each of the tasks needs a distinct set of strategies.

Parasuraman		AvantGuard
Intel. Acquisition	Look	Site selection
Intel. Analysis	See	Photo examination
Decision	Choose	Threat Assessment
Execution	Act	Convoy reroute

Fig 6.1 AvantGuard tasks in Parasuraman space

6.3 Adaptive Levels of Autonomy

AvantGuard seeks adaptive algorithms that adjust autonomy levels in response to events. Events include mission phase change, operator behavior, pop-up threats, equipment malfunction, etc.
Certain algorithms are recognized now. More will added during the next two years, as will a facility for the researcher to design original algorithms.

6.3.1 Initial Algorithms for Adaptive Levels of Autonomy

6.3.1.1 Crisis Driven

Begin at **LoA 2**, (very little automation.)

If Subject does nothing, switch to **LoA 6** (management by exception) just before disaster strikes.
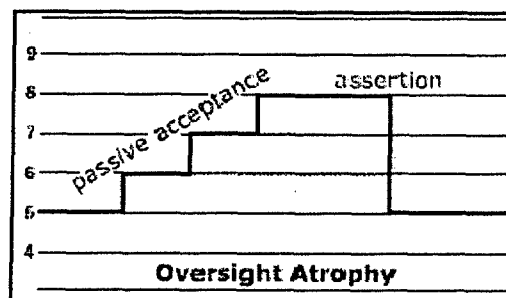

Crisis Driven
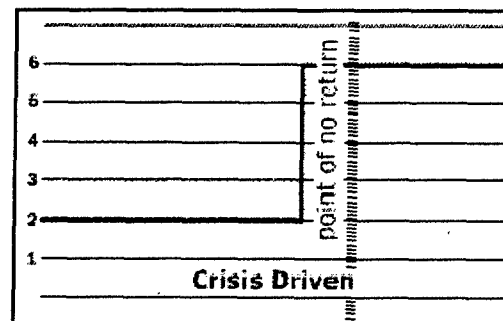
6.3.1.2 Oversight Atrophy

Begin at **LoA 5** (management by consent)
If subject accepts nothing- elevate to **LoA 6**
If Subject vetoes nothing, elevate to **LoA 7** (act and report action)
If Subject corrects nothing, elevate to **LoA 8** (report only on request)
If Subject asks to see action, revert to **LoA 5**
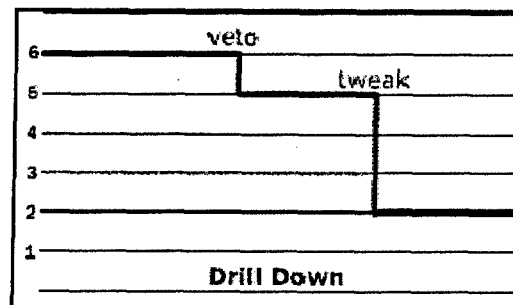

Oversight Atrophy

6.3.1.3 Drill Down

Begin at **LoA 6** (management by exception)
If Subject raises an exception, descend immediately to **LoA 5**
If Subject continues to assert control by tweaking suggested action, descend to **LoA 2**.

Drill Down

6.3.2 User Defined Adaptively

The researcher can design a pattern of behavior which implements an original strategy for adaptive Level of Autonomy. The pattern is defined as a series of responses to various events. A Finite State Machine can manage these responses by treating them as individual state transitions which are easily and unambiguously encoded as truth table logic.

Researchers may avoid working with raw finite state machines. GamesThatWork has begun an exploratory cooperation with Stottler Henke, a company that has developed a Behavior Editor for the USAF. Rather than introduce a new way to specify AI algorithms to Air Force researchers, it may be possible to incorporate Stottler Henke's SimBionic engine, which will allow use of the behavior editor which is designed for intelligent non-programmers to use and has adherents through the USAF [Stottler].

Events	Initial state	State transitions									
		1	2	3	4	5	6	7	8	9	10
User requests suggestion		3	3	3	4						
User accepts suggestion				3	4	5					
User makes choice from option list				2							
Tweak Node by Node		1	2	2	2	3	3				
Time Out (no user response)		2	3	4	5	6	7				
Reopen and Change Routing Decision		1	2	3	3	4	4	4	4	4	4
Failure* due to Inaction		3	4	5	6	6					
Failure* due to Action		3	3	4	4	5	6	7	8	9	10

* "Failure" event occurs when convoy enters an active threat area.

Fig 6. 3.2: Finite State Machine truth table used to program LoA adaption

This table encapsulates the transition rules for a finite state machine.

Each row of the table represents a particular event during the execution of the experiment. The events include both user actions and internal simulation results. (Only a few examples are presented here.)
Each column represents a Level of Autonomy at which the simulation can be working when the event occurs.
Each cell in the table shows the new Level of Autonomy which results when the event occurs at that level. Grayed cells reflect the fact that all events cannot occur at all Levels of Autonomy.

For example, if the User requests a suggestion from a UAV at LoA 1 or 2, the UAV will adaptively switch to LoA 3. If asked again for a suggestion, it will remain at LoA 3.

6.3.3 Adaptability Designed In

AvantGuard's simplified arrangement of tasks may be still too complex for certain studies. Five tasks might be too many moving parts. For example, the current design specifies two actions in the Parasuraman first domain: (Site selection and Flight planning). An experimenter might choose to eliminate the latter, fairly mechanical step and remove it cleanly from the subject's vision. By setting the task to LoA 10, the task disappears -performed automatically and never presented to the subject.

7   Five Tasks in AVANT GUARD
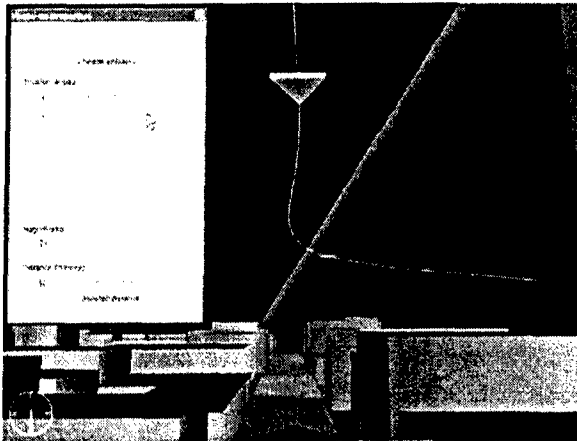
7.1 SITE SELECTION

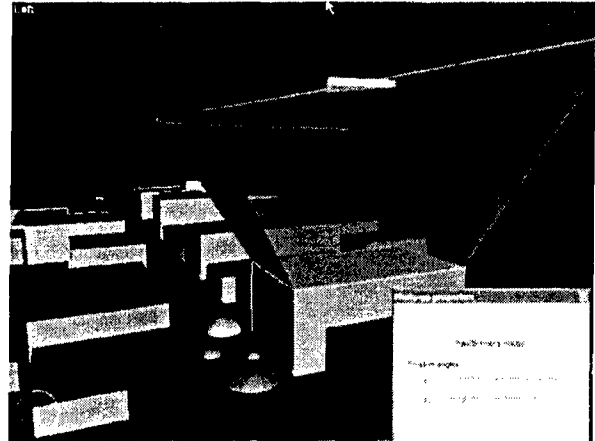Fig 6.1a Streetfront site and associated flightpath.

Fig 6.1b Rooftop site near four previous incidents.

7.1.1   Task:

The operator knows the convoy route and the past history of attacks in this area. The operator must choose those sites which require coverage and determine from which angles they should be seen. Specifically the operator marks the areas to be photographed by the UAVs. These can be particular building faces, rooftops, intersections or entire street fronts. The operator has a map of the town. This is a full three-dimensional (3D) map, including terrain and individual building elevations, which AvantGuard can render in cartographic or videogame mode.

7.1.2   Interface:

The operator has both map and 3D model and an instant, smooth, automated transition between the two. The operator can select sites by example – by pointing the 'camera' (first-person point of view) at any scene in the 3D model, and clicking a shot. A UAV will fly to this location and camera orientation and send back a photograph.

The Operator can also indicate directly what is to be photographed, by clicking on it. Power tools allow one to choose a street easily – with or without the facing building fronts. A very precise degree of control is available to an operator who wants to select exactly the angles and distances from which the site should be seen.

7.1.3   Parasuraman Domain 1:

Site Selection, along with Flight Planning, is part of "Look" (intelligence acquisition). Of the two, it is the creative task: determining the dangerous points along the convoy route.

7.1.4   Autonomy Levels:

At the Level 1, the operator selects each shot in teach-by-example mode. At higher levels the system selects coverage along the route. Some levels call for operator coverage choice, street-by-street tweaks, or plan confirmations. The highest do not require this. At Level 10, of course, the task disappears into full automation.

7.1.5   Error:

AvantGuard must accurately model not only functional autonomy – but also errors in autonomy. Site selection errors are simple: False negative means the omission of suspicious sites. False positives include both marking harmless sites and dangerous sites that are off the route.
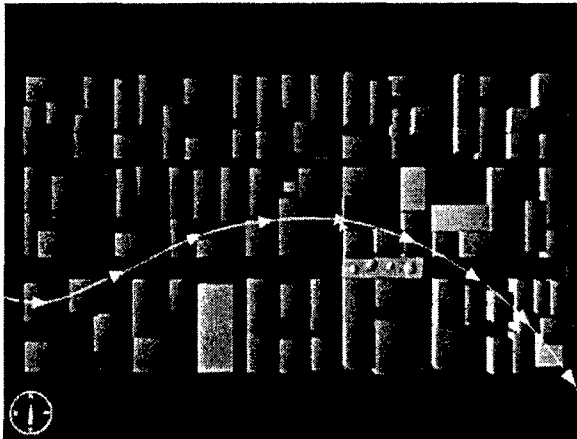
7.2 FLIGHT PLANNING
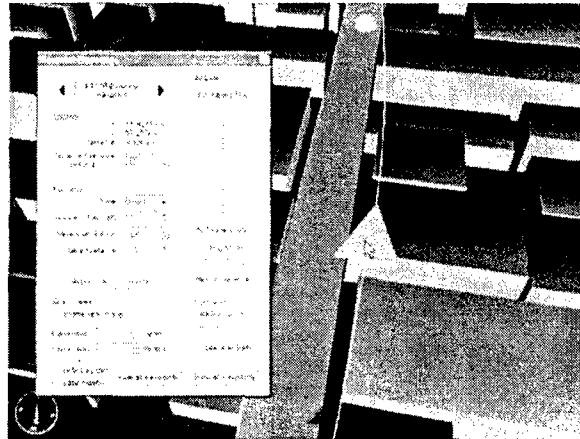

Fig 6.2a: Flightpath defined by waypoints, topdown view.

Fig 6.2b: Waypoint dragged in 3D, with property sheet.

7.2.1   Task:

The operator designs the flightpath of each UAV. The object is to efficiently fly by the surveillance sites. The plan must maximize the number of sites visited, and must also time them properly. The most useful photo is one taken just before it is examined. The most meaningful time to examine the photo is at the last possible moment – just in time to detour the convoy if needed.

7.2.2   Interface:

Flightpaths are set by establishing waypoints. Each UAV (or formation of UAVs) flies a curve-fit path (Hermite spline) along the sequence of waypoints. The operator is afforded both a top-down map interface and full 3D flight planner.
The top down map view is well suited to large scale overall flightpath decisions:
- assign photo op coverage to particular UAVs
- choose order of coverage by each UAV
- deconflict UAV flightpaths
- arrange overlap and multi-angle coverage

The 3D view allows the operator to
- optimize viewing angle, especially for urban scene
- avoid terrain and obstacles in low altitude flight
- establish clear lines of sight

In either view waypoints can be established – and dragged anywhere. The waypoint altitude can also be easily adjusted - either with a slider in the properties window or by dragging with a mouse button chord.

7.2.3   Parasuraman Domain 1:

Flight Planning, is also part of "Look" (intelligence acquisition). Unlike Site Selection, the job of directing UAVs to cover a set of sites has an optimal solution. Computer algorithms have no disadvantage in addressing this task.

7.2.4   Autonomy Levels

At the Level 1, the operator sets each waypoint. Level 2 provides 'wizard'. Each subsequent level offers a more robust routing solution using established algorithmic approaches to the Traveling Salesman Problem, (TSP) the classic, well-studied puzzle of computational mathematics.

7.2.5   Error:

AvantGuard models autonomy errors by photographing sites from poor angles and distances. It can produce inefficient paths. And it exacts a high cost in processing time, delaying the responsiveness of the autonomous system.
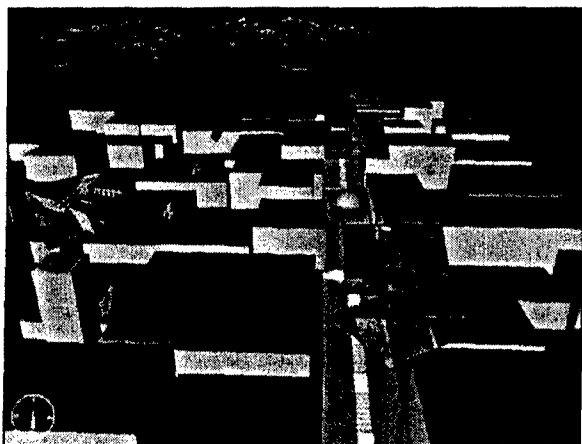
7.3 PHOTO EXAMINATION

Fig 6.3a: Sensor image stream - embedded in scene.

Fig 6.3b: Image examination with high-resolution inset.

7.3.1 Task:

The operator examines incoming sensor data for indicators of threats. The operator looks for characters in threatening poses: holding or hiding weapons, ducking behind walls and parapets, suspicious use of binoculars, cell phones, or batteries.

The operator reviews low resolution pictures downloaded from the UAVs. Bandwidth constraints require that high resolution imagery is downloaded from the on-board UAV cache only on operator request. The operator selects subsections ("chips') within the photographs to acquire high-resolution detail. The operator must balance the need for detail with the bandwidth cost and must act before the cached image on the UAV has been discarded.

7.3.2 Interface:

The operator picks photos directly from the 3D scene. They are embedded in the scene corresponding to where they were shot. Once chosen, photos sweep into flat view floating over the symbolic 3D view. High resolution chips are downloaded by simply dragging out areas within the image.

A toolbar on the bottom offers the red, yellow, green judgment buttons. It also has a suite of tools to allow the operator to navigate spatially and temporally through the image database.

7.3.3 Parasuraman Domain 2:

Analysis of sensor intelligence – such as examination of surveillance photos, is Parasuraman's second domain (See).

7.3.4 Autonomy Levels:

At Level 1, the operator has only simple tools for image management. Higher levels order the photos intelligently. True autonomy begins with Automatic Target Cueing (ATC). This begins by directing the operator's attention and progresses to filtering the image stream. This advances into more assertive systems of Automatic Target Recognition (ATR).

7.3.5 Error:

Autonomy here is problematic: The science of machine vision is imperfect. The consequence of error can be grave. But most of all, the entire problem is difficult. Locating humans is not the problem. The goal is to distinguish threats from neutrals. A man in a threatening pose is easily recognized by a human, but not by a machine. And context is important. A shovel is generally innocuous, but in certain contexts it is more damning than a Kalashnikov.

Simulated errors in ATC must be accurate. The system cannot offer a random point in a random photograph. It must select man-like imagery, and other images that closely resemble known threat patterns.
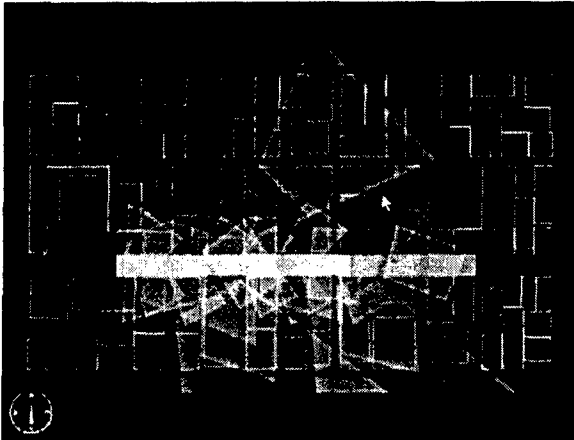
7.4 THREAT ASSESSMENT

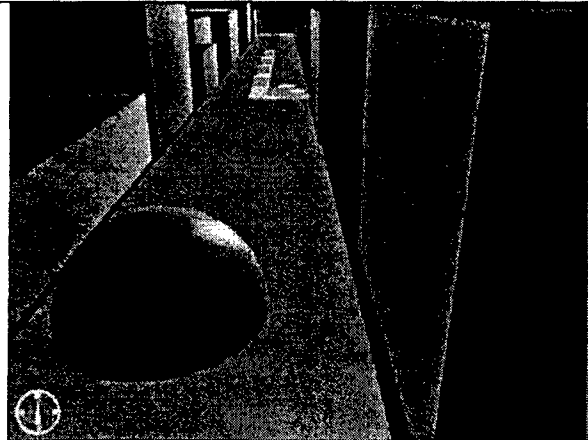Fig 6.4a: Projecting aggregate footprint of threat images.　　Fig 6.4b: Establishing a "No-Drive" zone.

7.4.1　Task:

The operator identifies active threats and makes a judgment on the safety of a street segment (one block or intersection). The operator bases this judgment on suspicious photos of this area. If they indicate danger, the operator marks the individual street segment as a threat. These accumulate to form the Threat Map. The decision usually requires the operator to integrate the content of several photos, perhaps the same area viewed from different angles or monitored over a period of time.

7.4.2　Interface:

The operator works primarily in an overhead view. Footprints of the photographs are projected onto the map, allowing the operator to readily locate red-flagged photographs. Clicking on a footprint displays the photograph in context. The operator sees the image from the point of view of the sensor that acquired it.

The normal image examination tools are available, but of limited value. The operator can 'look through" the picture at the model beneath it. By looking at all the overlapping suspect photographs, the operator evaluates and precisely locates the threat. If it is determined that the Threat is severe, a Threat Marker is placed on the map.

7.4.3　Parasuraman Domain 3:

Threat Assessment falls in the third domain (Choose). A pattern of danger has been established and a judgment must be formed on its significance.

7.4.4　Autonomy Levels:

Autonomy can provide reasonable threat determinations since the photographs themselves have already been examined and judged. A variety of algorithms (among them fuzzy logic) suggest themselves, and the levels of autonomy simply involve shifting authority from the human operator to these algorithms.

7.4.5　Error:

The errors that these algorithms produce will not be hard to simulate. These will result from poorly biased discrimination – either excess or insufficient caution.
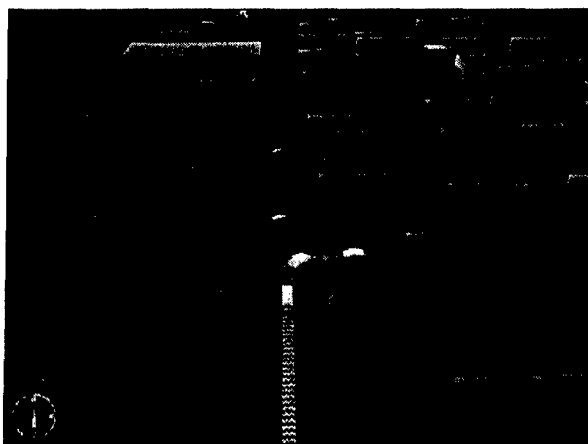
7.5 ROUTE SELECTION
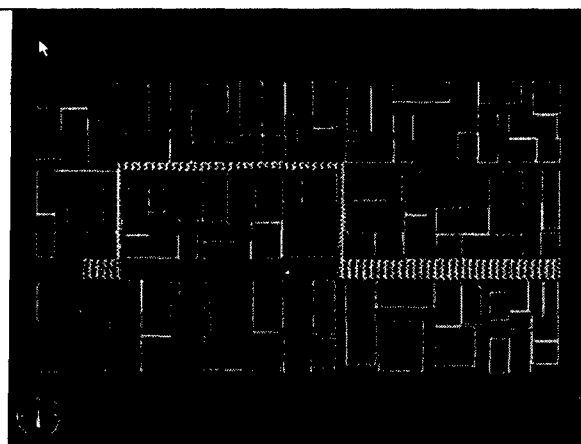

| Fig 6.5a: The convoy is detoured around the threats. | Fig 6.5b: Map view of the same scene. |

7.5.1 Task:

The operator maps the best street-by-street route based on avoiding threats. Secondary considerations in the routing decision include the incident history (avoid neighborhoods that have been proven dangerous) and the characteristics of the street and structures (prefer broad avenues and low buildings).

7.5.2 Interface:

The operator will find it easiest to work in the Map View – the two-dimensional, top-down, North-up perspective. The most natural interface for a route decision is an ordinary flat map, and it will feel familiar. However an AvantGuard innovation – the 'Flywheel[3]'device allows the operator to instantly swoop the point of view to any angle, so that lines of sight and vantage points can be readily assessed. Just as easily, the Map view can be restored.

While making Routing decision, the convoy position and its destination are visually prominent. The streets are easily seen. A series of street segments are highlighted. These show the current convoy route. Some segments are clear, and some are blocked by Threats that require the convoy to detour. Incident history is visible, but somewhat less prominent.

When the mouse hovers over the route, it intensifies in brightness. Routing "handles" appear at each intersection. The operator can click drag a handle to a new intersection. The convoy reroutes efficiently through the new intersection. The criterion used to calculate efficiency depends on the selected Level of Autonomy.

7.5.3 Parasuraman Domain 4:

The execution of the decision is to reroute the convoy. This is Level 4 (Act).

7.5.4 Autonomy Levels

Simple point-to-point routing can be accomplished with great reliability using Dykstra techniques. Accurate graphs and properly weighted costs result in optimal paths. Sheridan's autonomy levels are implemented by this algorithm.

7.5.5 Error:

In addition to stochastic false positives and false negatives, the system has a more interesting failure. Veterans of Iraq report encountering vivid danger signs (such as a burning vehicle) that served only to detour a cautious convoy directly into the real ambush. Such scenarios can be set up in AvantGuard, and will usually trap the autonomous systems.

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[3] The Flywheel device is a user interface construct, designed around the mouse middle button and wheel. It allows the user to grasp any point on an object or terrain and to 'fly' relative to that point in three-space. An unanchored 'free flight' mode also exists.

BEYOND PHASE II

The initial challenge is simply to achieve the goals of Phase II and to realize this existing design. Phase II projects twenty four months of development. During those two years – and afterward - AvantGuard must remain relevant to the challenges of the real world. It must anticipate change.

Today AvantGuard models active urban insurgency. Only a grim pessimist would predict that American forces will still conduct open warfare in the cities of Iraq in 2007. But withdrawal is also improbable. Most likely, Americans will be engaged as armed peacekeepers.

Peacekeepers must fight differently: A force that supports the rule of law cannot ignore the law. Battlefield tactics that might be justifiable today will be unacceptably brutal when the goal is to stabilize a civil society.

Just as UAVs in the game scout ahead of the convoy, AvantGuard is itself a look-ahead mission. It aims to address this upcoming role. Precise acquisition of intelligence will be more important than precise delivery of munitions. Good UAV surveillance supports a commander's search for a wise plan. Good UCAVs support only one plan.

In this light, consider the fidelity of AvantGuard's current scenario. It is not a very accurate model of a mature resistance. In a peacekeeping situation, adversaries will not congregate conveniently on roof tops. The cues of danger will be based on long baseline, high detail observations. Breaks in the pattern reveal danger – often through negative observations of civilian behavior ("Where are the school-kids today?", "Usually there are cars parked out front here."). AvantGuard is extensible. With strengthened archives, it can support this patient patrol work and other new missions. As military roles evolve, as adversaries are better understood, more accurate scenarios will be built.

CONCLUSION

Phase I expressed a commitment to three goals: the primary question of autonomy, the application of autonomous vehicles in a convoy protection mission and the demonstration of videogame principles to controlling this application. The work just concluded demonstrates a vision for achieving these goals, a plan for implementing the vision and a sound probability of success in execution of the plan during Phase II.

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